

# 2<sup>nd</sup> Generation Airborne Precipitation Radar (APR-2)

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# Airborne Precipitation Radar (APR-2) - Overview

- Dual-frequency operation with Ku-band (13.4 GHz) and Ka-band (35.6 GHz)
  - Geometry and frequencies chosen to simulate GPM radar
- Measures reflectivity at co- and cross-polarizations, and Doppler
- Range resolution is  $\sim 60$  m
- Horizontal resolution at surface (DC-8 at 11 km altitude) is  $\sim 1$  km

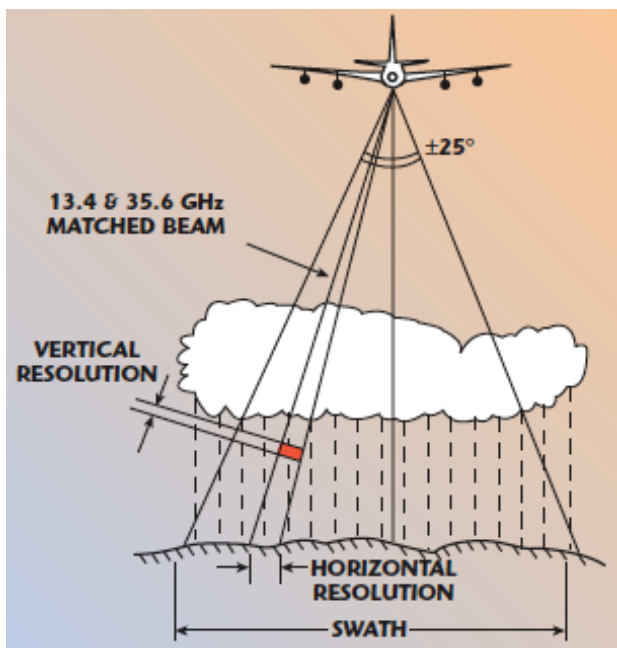
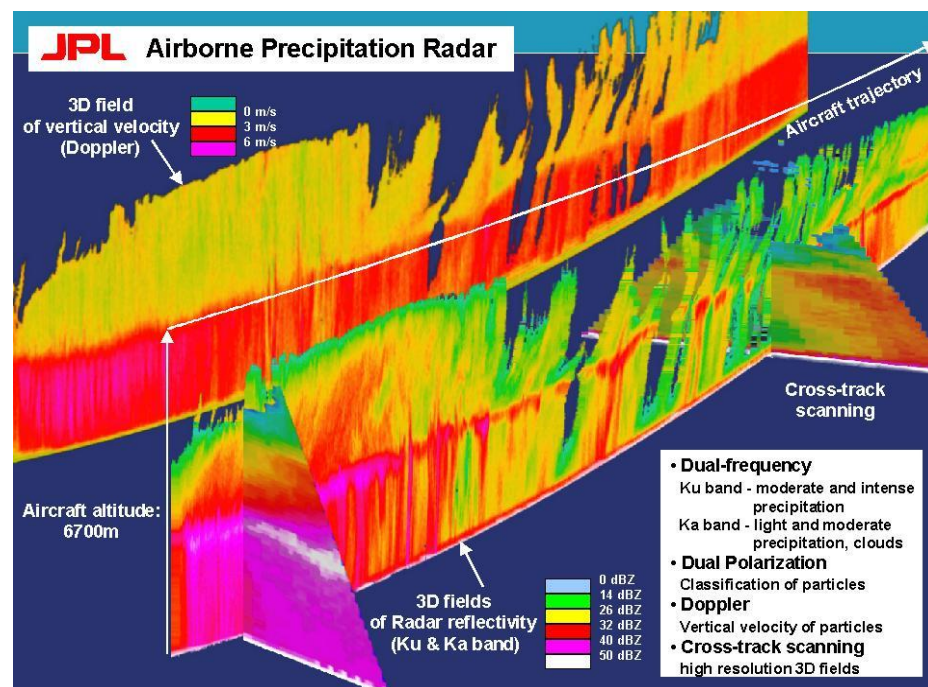
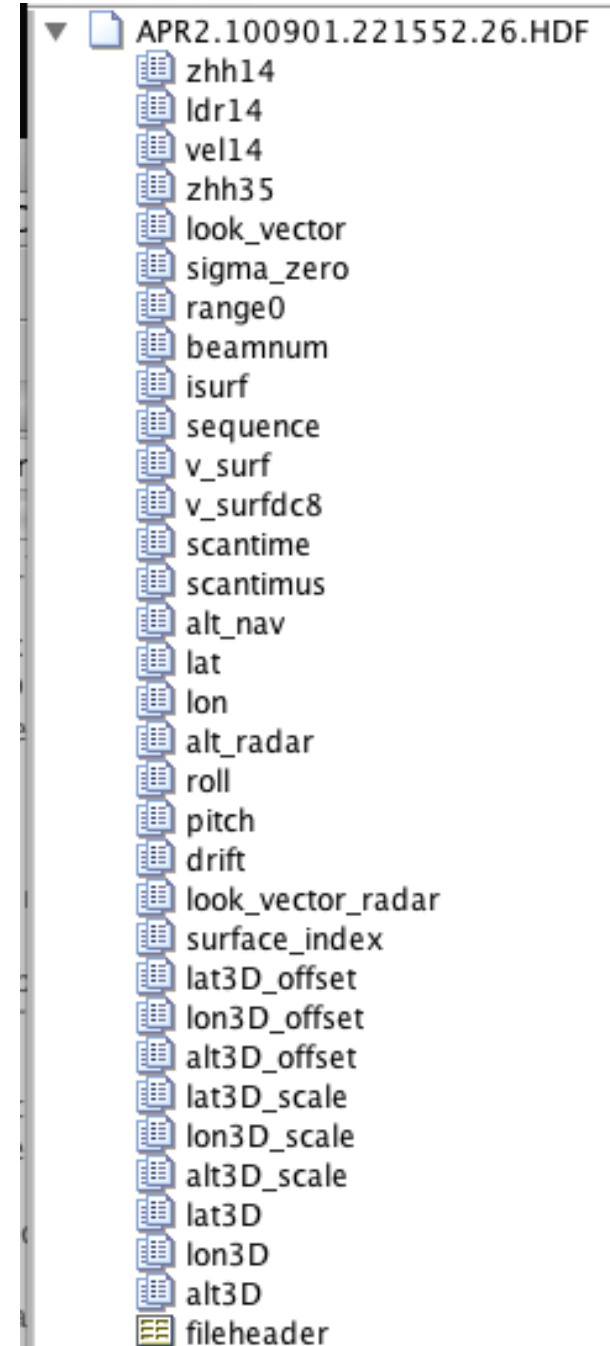
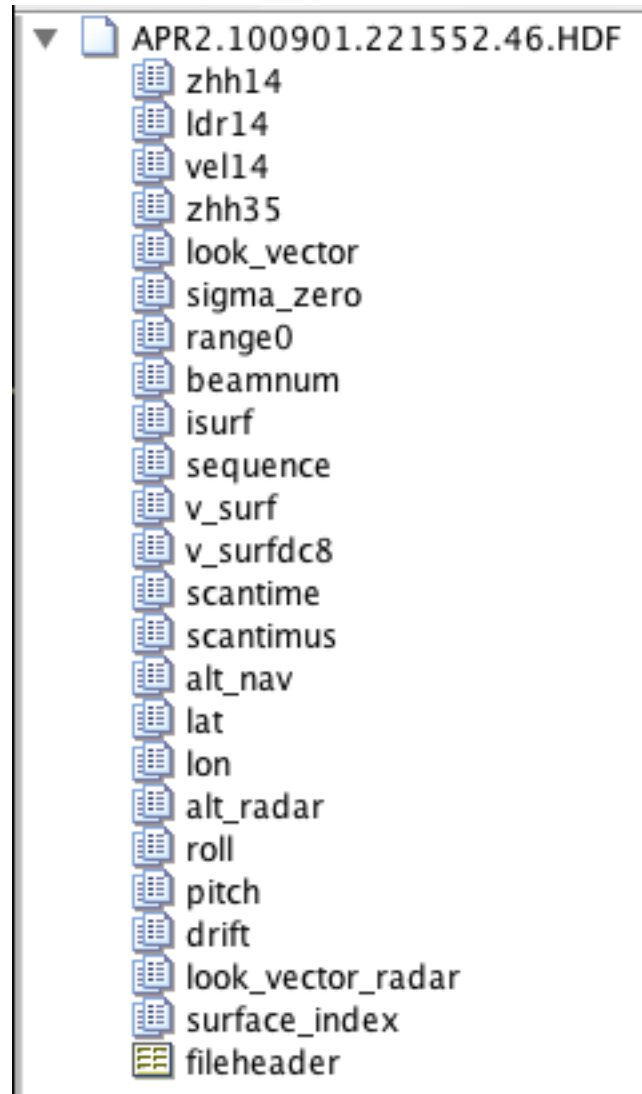


Image below shows 3D nature of APR-2 data; 50-degree data wedge underneath flight track



# Final Data Set in Archive

- Version 46 – standard APR-2 product
- Version 26 – includes geolocation for each bin; 70% larger
- Volume variables, including lat3D, etc are 550 bins x 24 beams by nscan
- Also can produce ldr35 and vel35; noisier and not needed by most researchers



# Data Quality

- Reflectivity calibration is within 1.5 dB
  - Based on 10-degree incidence  $\sigma_0$  at Ku-band
  - Based on Mie scattering calculations in light rain at Ka-band
- LDR measurements are OK to near -20 dB; LDR lower than this is likely contaminated by system cross-polarization isolation
- Velocity is motion-corrected total Doppler, including particle fall speed
- Aliasing can be seen in some places; can usually be dealiased with following algorithm

xa=max unambiguous  
velocity (Ku-band), 27.5 m/s

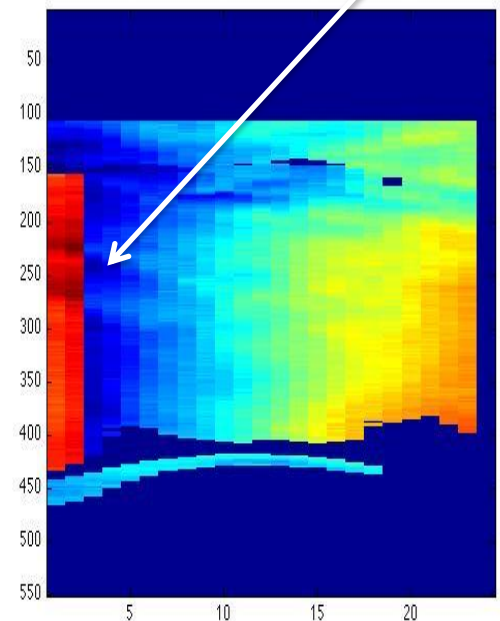
x0=input velocity volume

dx is velocity difference along  
each beam

Large jumps are assumed to  
be due to aliasing

```
dx=diff(x0,1,3);
dx(:,:,nbin)=zeros(nscan,nbeam);
ijump=find(dx>1.8*xa);
[i,j,k]=ind2sub(size(dx),ijump);
for l=1:length(i)
    bins=(k(l)+1):nbin;
    x0(i(l),j(l),bins)=x0(i(l),j(l),bins)-2*xa;
end
ijump=find(dx<-1.8*xa);
[i,j,k]=ind2sub(size(dx),ijump);
for l=1:length(i)
    bins=(k(l)+1):nbin;
    x0(i(l),j(l),bins)=x0(i(l),j(l),bins)+2*xa;
end
```

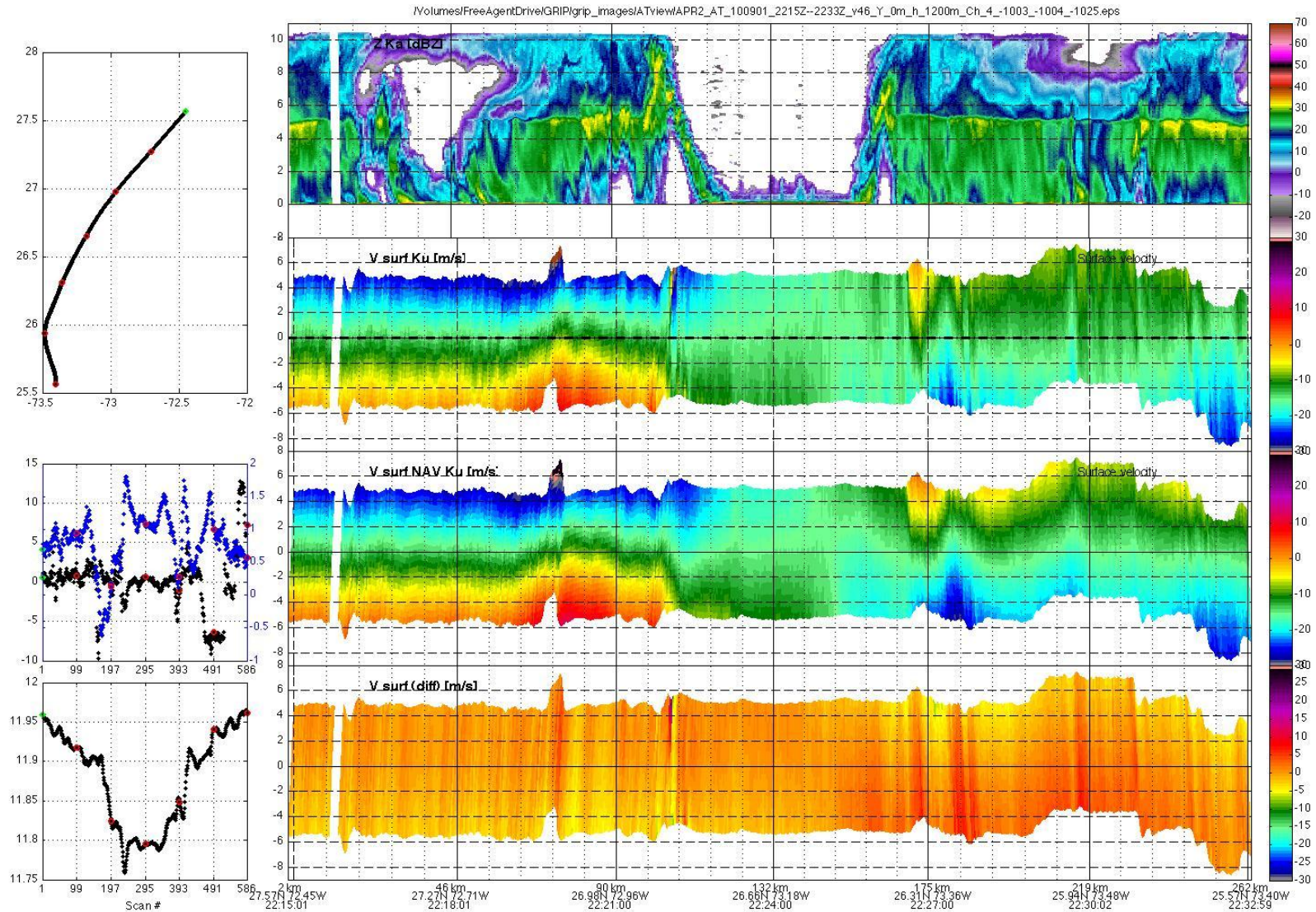
Not fool proof



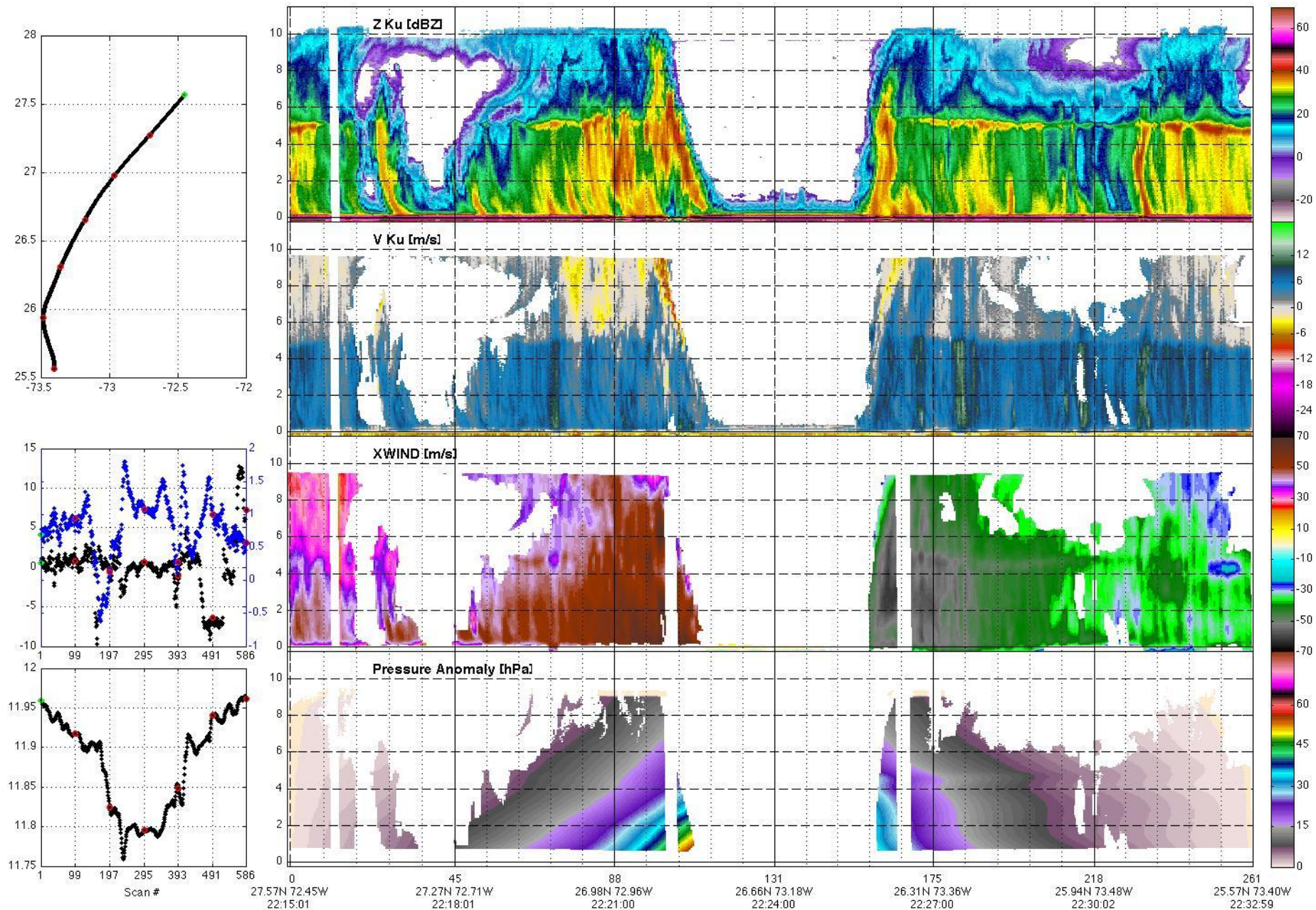


# Motion Correction

- Based on surface Doppler; correction using MMS also in archived files
- Example below from Earl on September 1 (used in following as well)



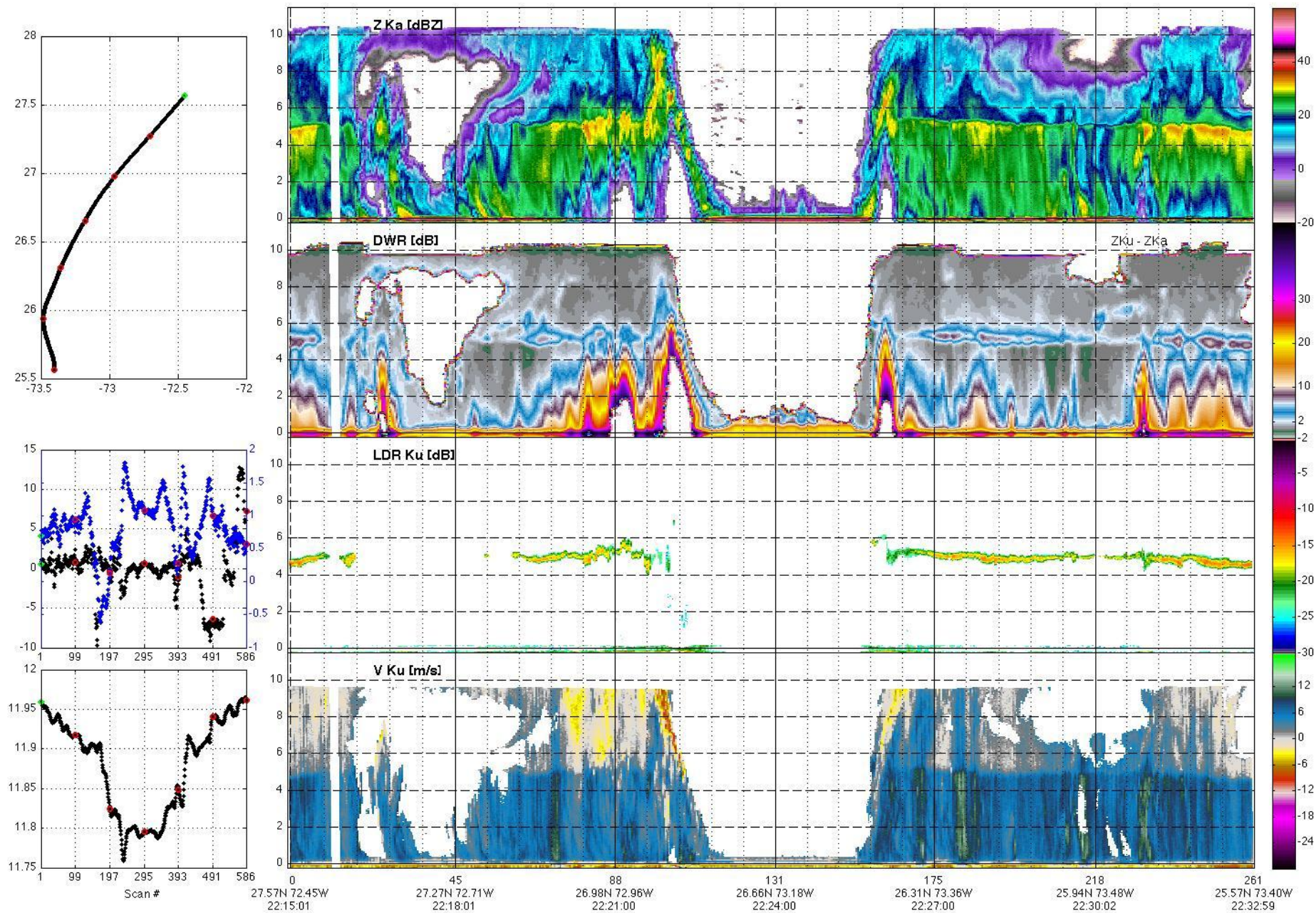




Pressure derived from xwind field and gradient balance (Smith 2006)

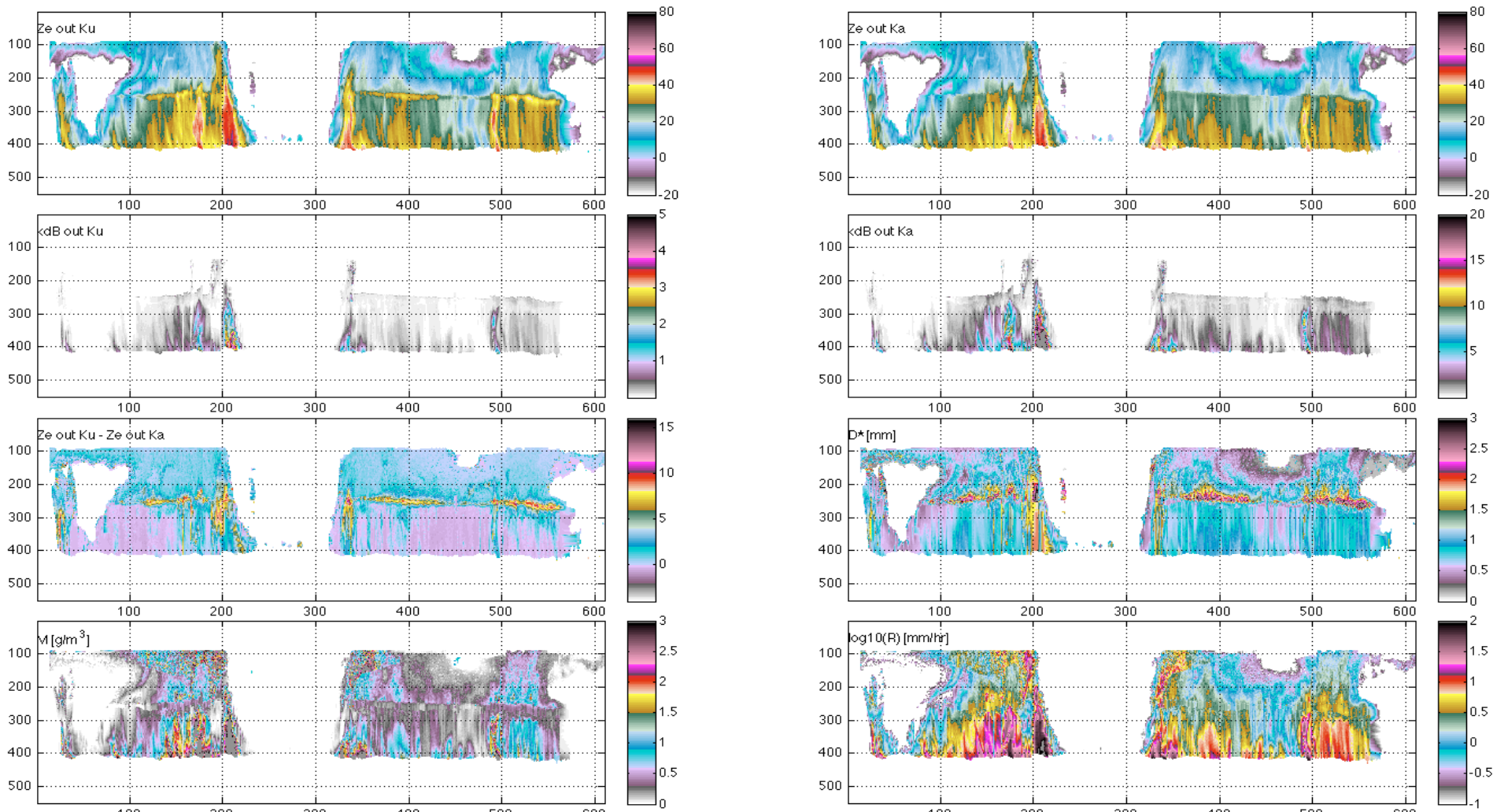


# Ka-band Z, DWR, LDR Ku, V Ku



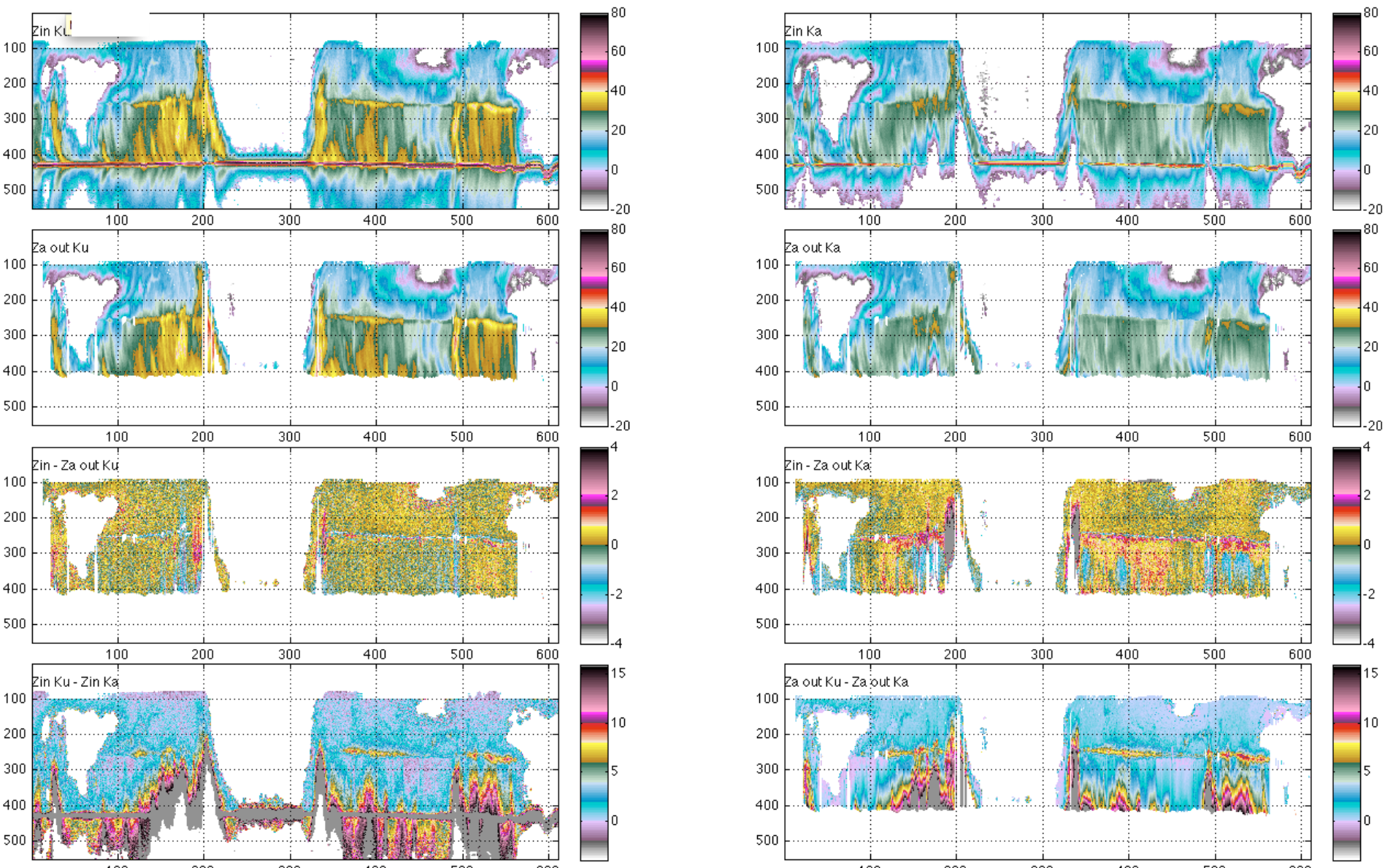
# APR-2 Retrievals

- Uses both frequencies when available, Doppler, LDR
- Fully Bayesian approach performs multiple (up to ~100) retrievals by perturbing PIA, and a priori mean particle size assumptions. Deterministic classification is used as input, but fractional populations of liquid, snow, graupel, etc are refined based on Rasmussen and Heymsfield.
- Final estimate is a weight average based on several performance measures.





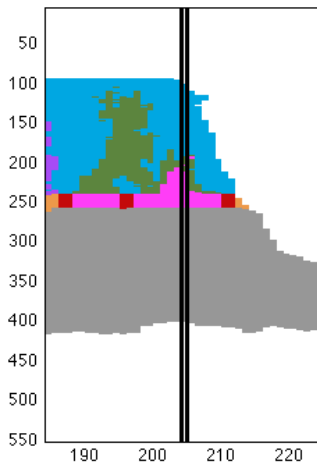
# APR-2 retrievals (goodness of retrieval)



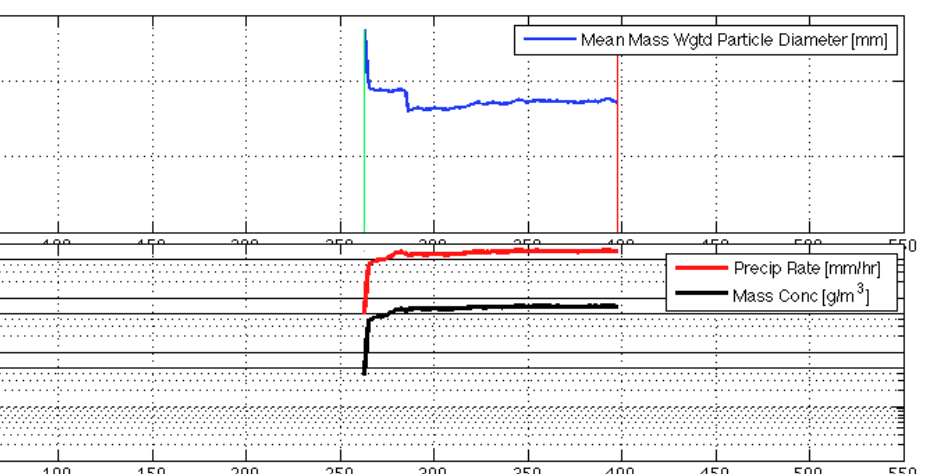
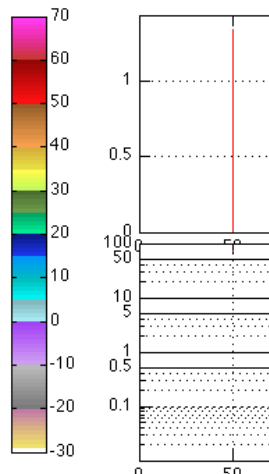
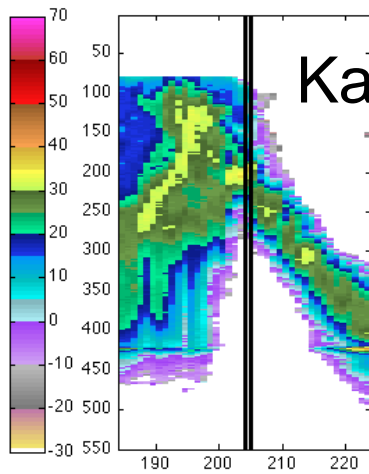
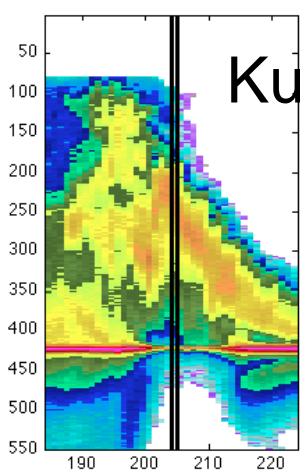
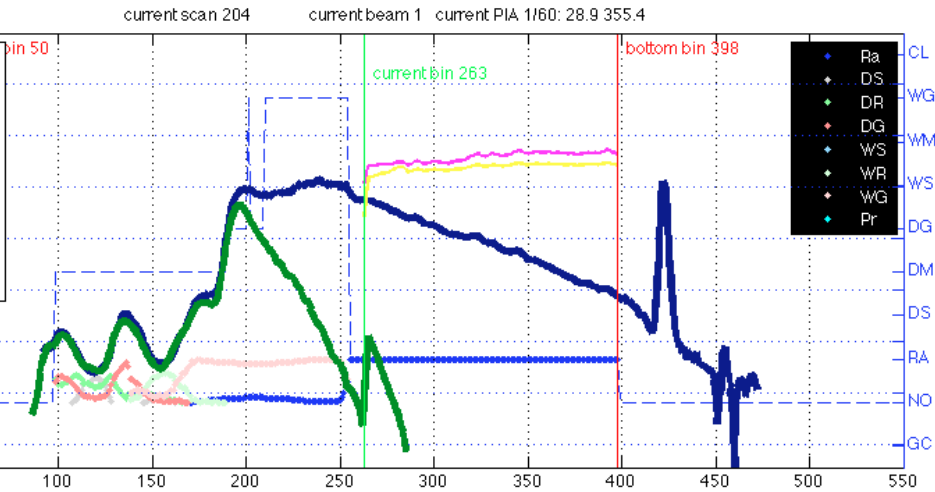
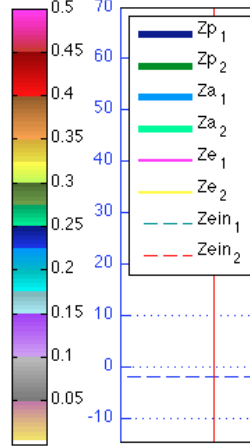
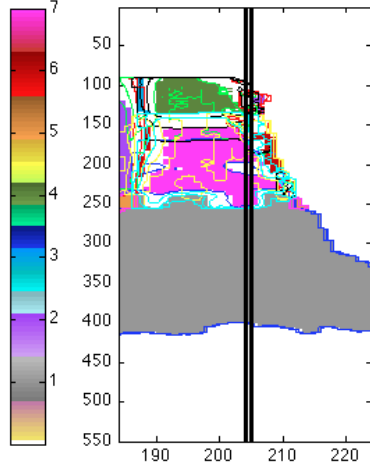
# Unusual Radar Profiles in Eyewall

- Retrieval failed on this profile due to unusual feature in Ka-band profile

CLASSin



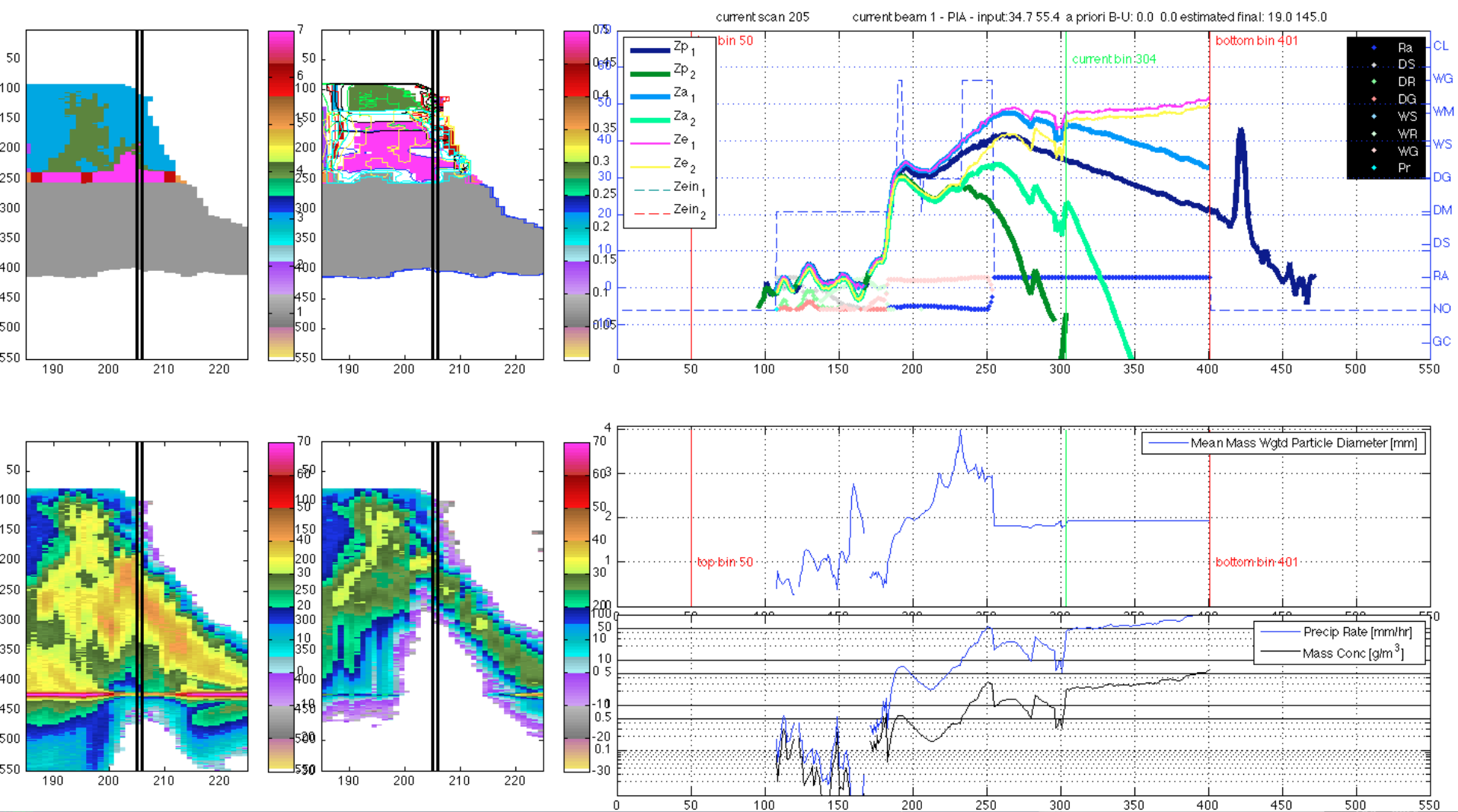
Fractions





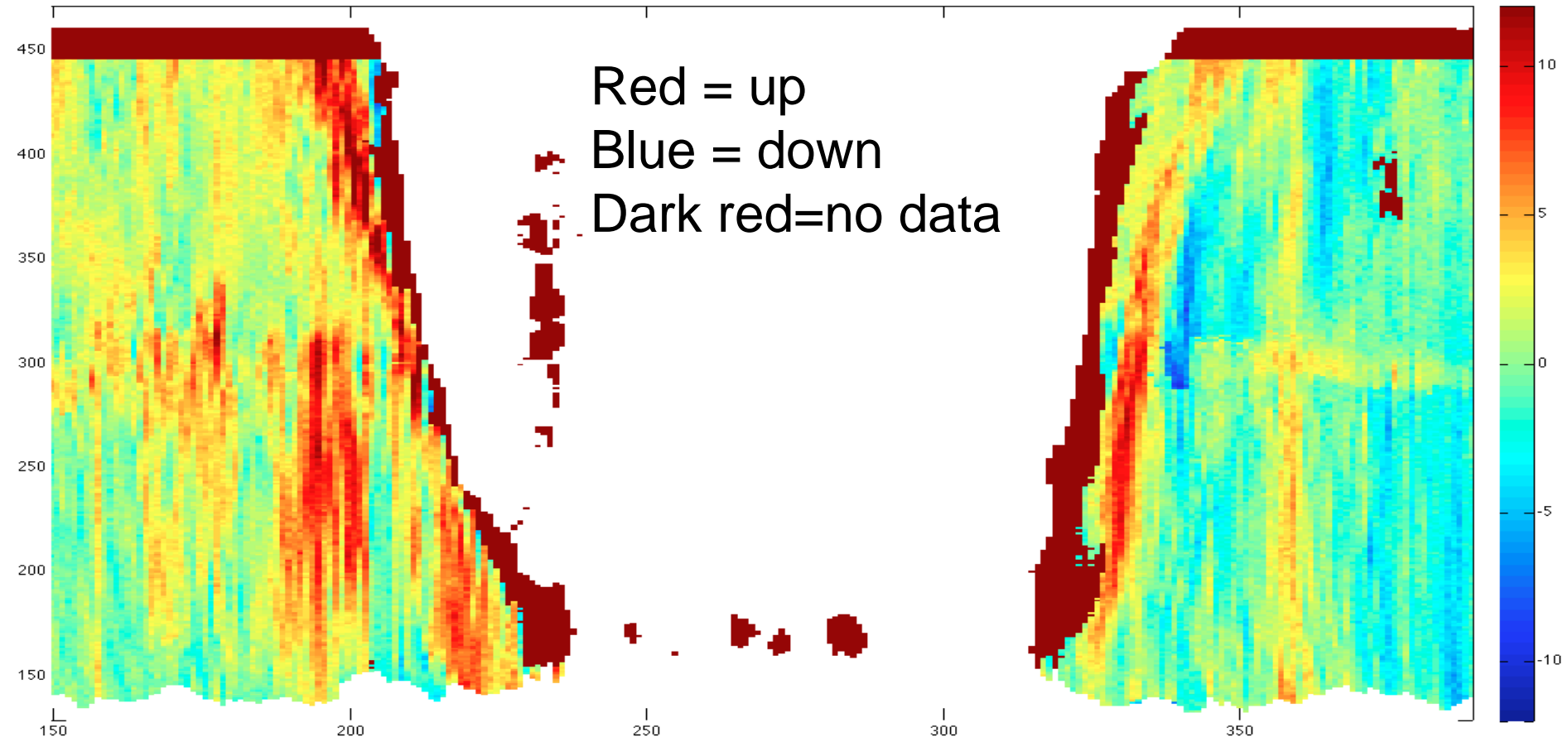
# Retrieval Works on Adjacent Eyewall Profile

- Mass-weighted mean particle diameter in rain near 2 mm
- Rain rate exceeds 100 mm/h



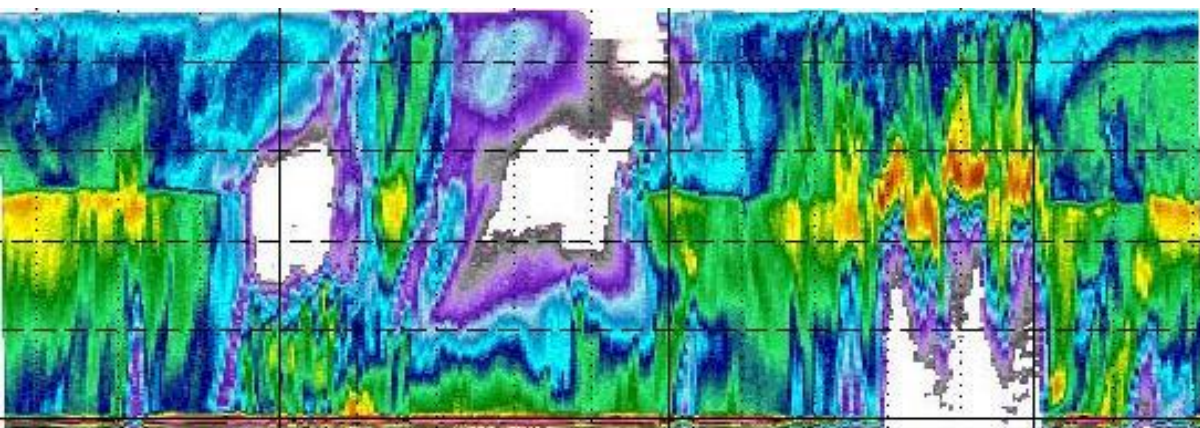
# Terminal Fall Speed Correction

- Simplest is to use v-Z relation, e.g.,  $v = 4 Z^{0.6}$
- Better is to apply full precipitation retrieval to dual frequency data; calculate terminal velocity from retrieved profile and remove from Doppler

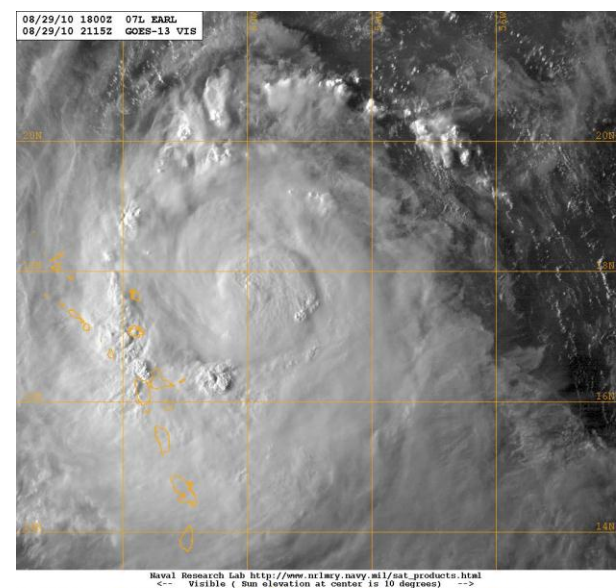
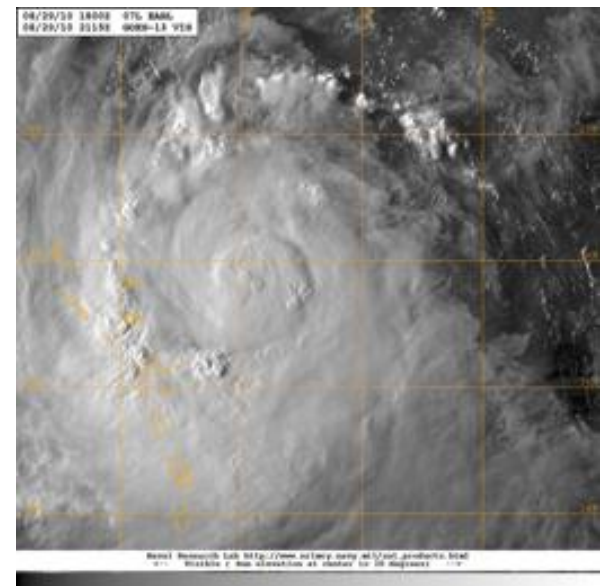
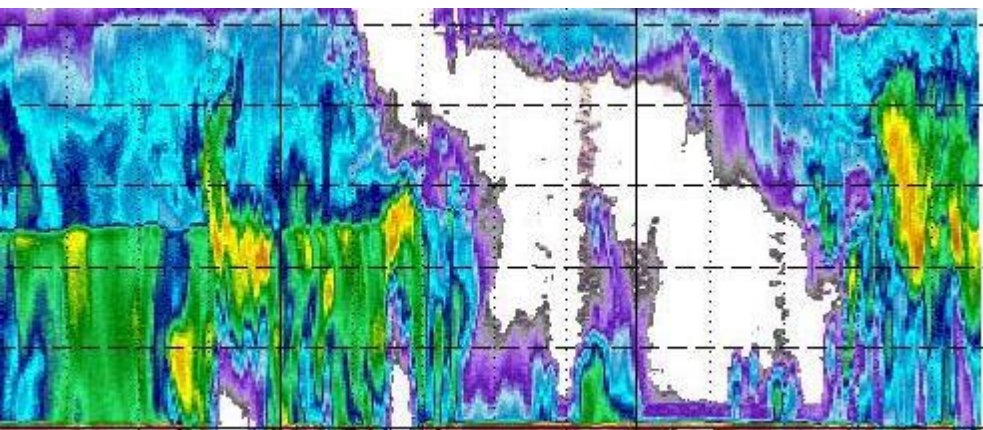




# Ka-band Views of Eye of Hurricane Earl – Aug 29

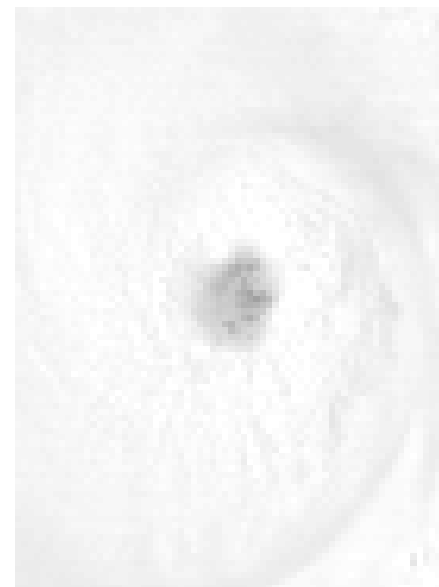
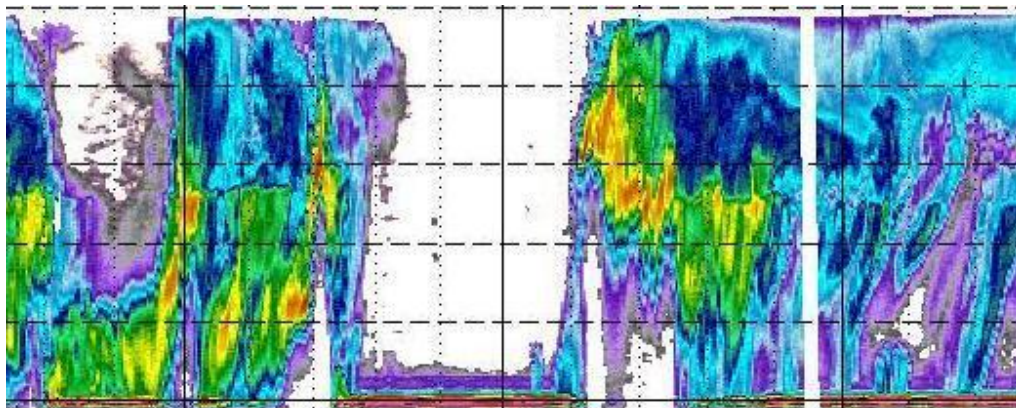


1730 upper; 2130 lower

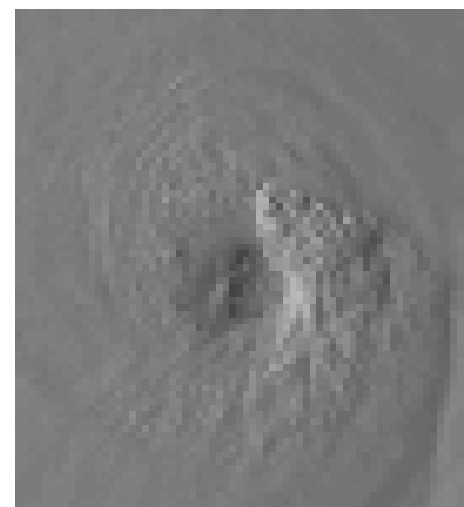
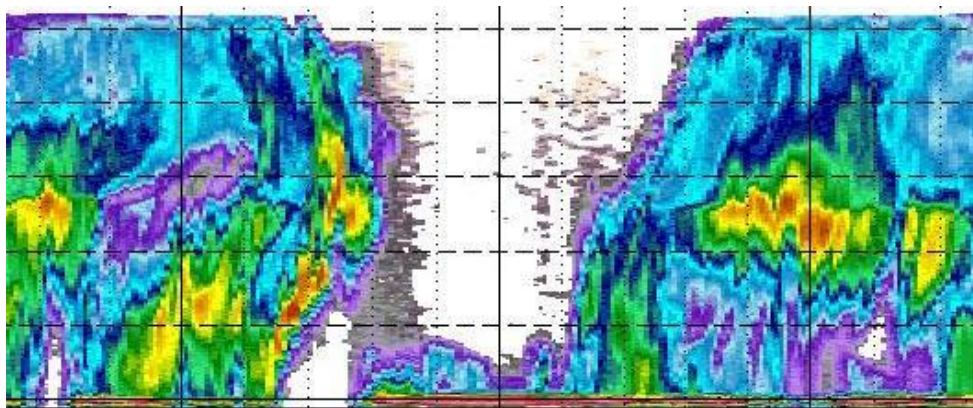


Eye seems to clear out during flight  
Velocity mostly downward in eye area

# Ka-band Views of Eye of Hurricane Earl – Aug 30

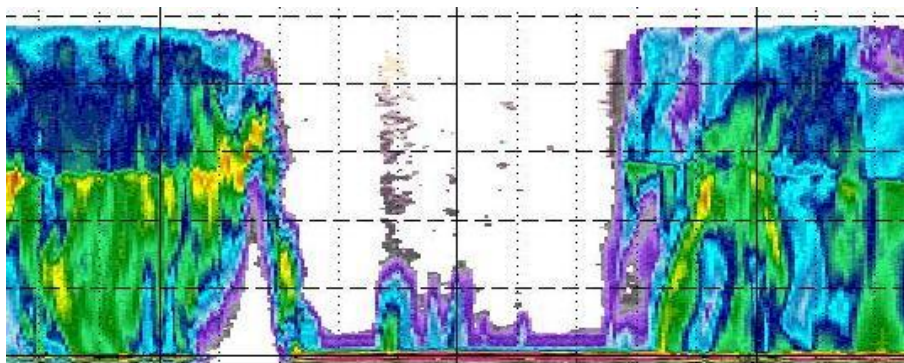


1830 upper; 2130 lower



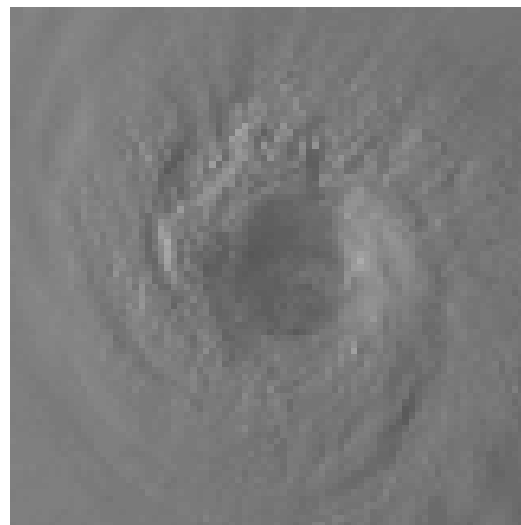
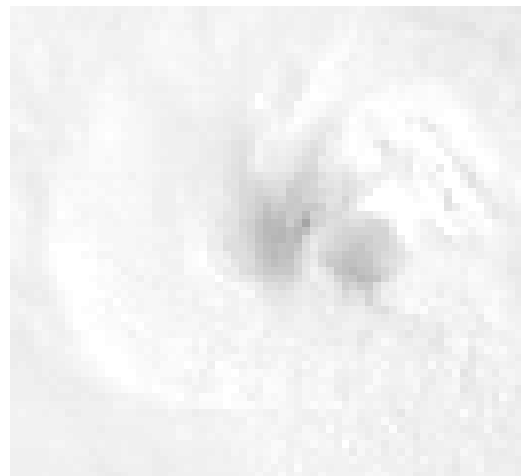
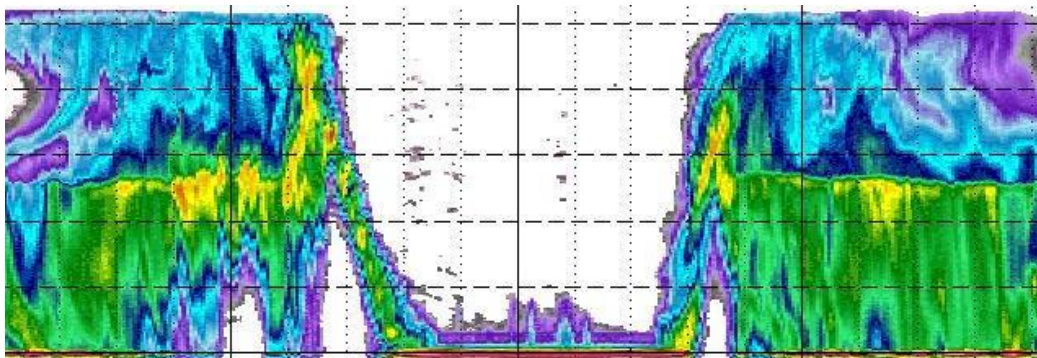


# Ka-band Views of Eye of Hurricane Earl – Sep 1



Thick low cloud with drizzle near center,  
also in GOES

1900 upper; 2230 lower



Summary: APR2 saw forming eye on 8/29; clear eyes on 8/30 and 9/1 but often with some cloud and showers; heavier clouds below 2 km

# Karl

- Collaborating with Comellas and Parodi on simulating genesis and RI of Karl with WRF
- Initial comparisons have focused on dropsondes and satellite IR (see poster by Comellas et al.)
- Plan to compare WRF results with APR-2 measurements as done in Parodi and Tanelli 2010 for TC4 data.

# Status and Plans

- Calibrated level 1 data archived
  - Reflectivity data quality good
  - Velocity at Ku-band also good but requires some care; recommend contacting us if you are working with data, especially velocity
- Cross-wind data is noisy but allows reasonable estimate of pressure field; density and temp fields require differentiation – results are mixed
- Ka-band data can detect very light rain and even some clouds
  - In addition to dual-frequency retrievals, we are also using it to examine Earl's eye
- Collaborations – put our measurements in the context of other observations and models